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# A NEW APPROACH USING VARIOUS REMOTE SENSING DATA FOR VEGETATION PARAMETER RETRIEVAL AS INPUT TO ECOSYSTEM MODELS

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## ABSTRACT

The objective of the following outline is to propose a method of combining various remote sensing data and to point out the potential of diverse remote sensing data as an input to local, regional or global ecosystem models. The combination of different data sources including several observing geometries and an ensured comparability of the retrieved data products demand for a uniform baseline of normalized ground reflectance data (geometrically, atmospherically, and BRDF corrected), which also provides the possibility of comparison between different sensors and observing geometries for calibration/validation purposes. Possible disadvantages of a spatial and spectral information loss have to be assessed, being a result of the necessary resampling and spectral convolution.

## 1. INTRODUCTION

Reflectance measurements are usually performed at a local scale and on a specific vegetation surface and therefore exhibit a limited significance for larger areas. During a field campaign of RSL in July 2004, a large dataset of spaceborne (MERIS, MODIS), airborne (HYMAP), and ground spectral information was acquired at the same time and of the same area. By combining this spectral information obtained by different sensors with different characteristics, the generation of a value added product is possible. The objective here is to propose an approach of how multi-source remote sensing data can be used as an input to local, regional or global ecosystem models. Therefore it is necessary to generate a uniform baseline of normalized ground reflectance. Various ground information is necessary either for correction or validation purposes. A BRDF correction is done by using spectrodirectional field measurements, which were performed with the RSL field goniometer system FIGOS [1] or by using modeled HDRF data. Further reflectance information of different vegetation surfaces is gathered by an ASD field spectroradiometer. Validation of the retrieved model output parameters is assured by using various measured structural and

biochemical vegetation parameters.

The Vordemwald study area (E 47°16' N 07° 53') is located in the canton of Aargau, Switzerland and covers an area of approximately 50 km<sup>2</sup> of mixed forest, cultivated fields and grassland. The field campaign was conducted by RSL in collaboration with the Swiss Federal Institute of Forest, Snow and Landscape Research (WSL).

## 2. DATA

Field measurements were performed in the second half of July 2004 at six different sites in the forest of the Vordemwald study area. The forest consists of two main coniferous species (*Picea abies* and *Abies alba*) and five deciduous species (*Fagus sylvatica*, *Acer pseudoplatanus*, *Fraxinus excelsior*, *Quercus robur*, and *Quercus rubra*). At each plot the trees were georeferenced, diameter at breast height (DBH), tree height, crown base, and crown dimension were measured. Three top of canopy branches were excised by a tree climber from each sampled tree. The plant material from the treetop is important in order to compare remotely sensed data with ground truth information. A handful of leaf samples were packed from each tree, stored in a cool environment, and transported to the lab for a variety of analyses such as chlorophyll, specific leaf area (SLA), leaf water content (LWC), and C:N ratio.



Fig. 1. Hemispherical photograph for the retrieval of canopy geometrical structure.

Hemispherical photographs were taken to determine Leaf Area Index (LAI) and Gap fraction [Figure 1]. The photos were acquired with a digital camera and a hemispherical lens converter. Additionally, a gas exchange experiment was conducted in the field to measure the leaf net CO<sub>2</sub> uptake as well as the stomatal conductance.

The leaf optical properties (leaf reflectance and transmittance) of broadleaf plant types representative for the study site were measured. Spectral properties of single leaves are essential to understand the interaction of the incident radiation with the vegetation. The optical properties provide the critical link between remote sensing data on the canopy scale and the physiological energy and mass transfer processes on leaf level.

The acquisition of spectral measurements involved an ASD field spectroradiometer coupled to an integrating sphere and a custom made light source for improved illumination. Both adaxial and abaxial sides of the foliage elements were considered for reflectance and transmission measurements.

In order to validate and correct the acquired airborne and spaceborne at-sensor radiance with respect to the observation directions, spectrodirectional measurements were performed with the RSL field goniometer system (FIGOS). FIGOS was therefore placed on a meadow at the intersection area of all three flight lines. The albedo normalized anisotropy factor ANIF of the observed meadow exhibits a slight bowl shape. The typical reflectance peak for vegetation in the backscattering region is less dominant than expected [Figure 2]. This effect might occur due to the specific constituents of the meadow, which included some white clover (*Trifolium repens*) leading to a higher reflectance at large observation zenith angles. Simultaneously, the direct and diffuse irradiance was measured with a MFR 7 sunphotometer in order to correct the measured hemispherical directional reflectances for the diffuse part of the incoming radiance [2].

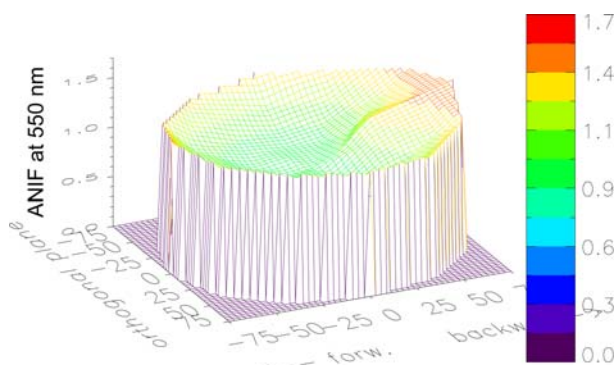


Fig. 2. Anisotropy factor of the observed meadow.

HyMap airborne hyperspectral imagery was recorded on July 29, 2004 during excellent weather conditions.

HyMap is an imaging spectrometer providing spectral coverage in the visible, near, shortwave and middle infrared in 125 bands with a bandwidth of 10-20 nm at 5 m spatial resolution. Three flight lines were acquired over the test site, two in direction NS and one in direction WE, in order to obtain spectrodirectional information.

Additionally to the imaging spectrometry data, MERIS (Full Resolution Level 1B) and MODIS (Level 1B) data were acquired. MERIS data was obtained one day before the HyMap and MODIS acquisition but under comparable weather conditions [Figure 3].

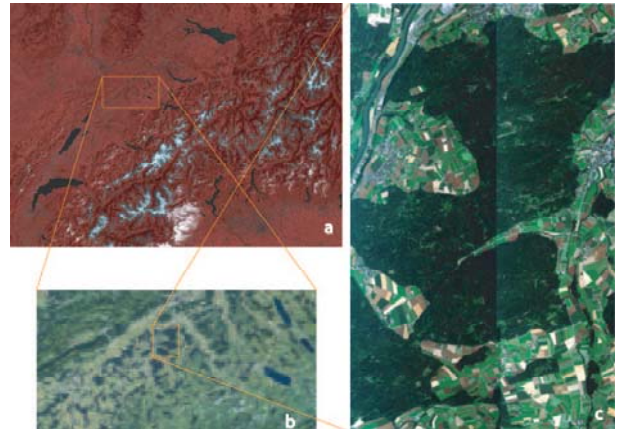


Fig. 3. a) MODIS 250 m spatial resolution, false color, b) MERIS 300 m spatial resolution RGB, and c) two HyMap NS flight lines with 5 m spatial resolution.

### 3. METHODS

To obtain ground reflectance, the acquired reflectance data of every sensor has to be atmospherically and geometrically corrected. The airborne image data is orthorectified based on the parametric geocoding procedure PARGE [3]. The parametric geocoding methodology considers the terrain geometry and allows for the correction of altitude and flightpath-dependent distortions in airborne imagery. The approach relies on several auxiliary data such as Inertial Navigation System parameters, Ground Control Points (GCP), and a Digital Elevation Model (DEM) describing the terrain. Orthorectified imagery is a prerequisite for the subsequent radiometric correction. The radiometric correction of the geocoded and orthorectified imagery is performed using ATCOR4 [4], a software tool to invert the radiative transfer code MODTRAN4. ATCOR4 provides surface reflectance and temperatures performing a combined atmospheric/topographic correction where the effects of terrain of the observed surface are accounted for.

The proposed approach for integrating various remote sensing data is given in Figure 4.

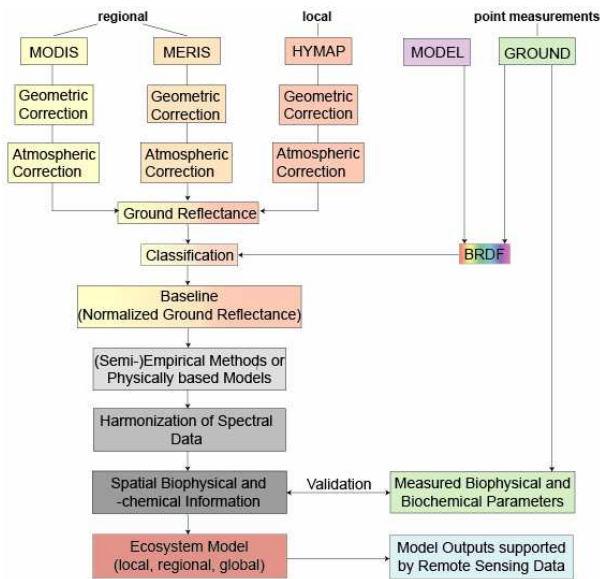


Fig. 4. Flowchart outlining the proposed approach for the usage of various remote sensing data as input to local, regional or global ecosystem process models.

**Classification:** After preprocessing the data, main landcover classes have to be determined. Classification is a prerequisite for the subsequent landcover specific BRDF correction, which is performed using either measured or modeled HDRF data. Local spectrodirectional observations are extrapolated across larger areas to retrieve corrected information.

**Baseline:** The atmospherically, geometrically and directionally corrected reflectance data are called baseline or normalized ground reflectance. This dataset serves as input to various semi-empirical and empirical techniques (e.g. vegetation indices, position of the inflection point of the red edge), physically based models (e.g. Prospect [5], Sail [6]), and analytical methods (e.g. Principal Component Analysis) for the acquisition of surface variables required by ecological models.

**Harmonization:** Since reflectance data of various sensors with different spectral and geometrical characteristics are combined, a convolution of the spectral data to the necessary bandwidth must be performed as well as a spatial upscaling to a common pixel size.

**Validation:** The retrieved spatial estimates of vegetation parameters are validated against ground truth data.

The verified spatial information can then be implemented into an ecosystem process model (e.g. Biome-BGC [7], PnET [8]). Ecosystem process models are important tools for applying the information

provided by remote sensing products to quantify fluxes of carbon and other elements. Physiologically based process models, applied in a spatially distributed mode, can assimilate and effectively integrate a diverse assemblage of environmental data, including information on soils, climate, and vegetation [9].

## 4. CONCLUSION

The proposed approach shows the potential of combined remote sensing data in various model outputs.

Remote sensing data can be acquired with various instruments (sensors) and methods, leading to a large and heterogeneous dataset. In dependence of the research objective, the appropriate sensor or method is chosen in order to minimize disadvantages. But there lies also a great potential in the combination of multi-source remote sensing data both for correction purposes of sensor artefacts or directional effects and for the generation of an added value product.

The proposed approach reveals the following advantages:

- the generation of a remote sensing based input to regional and global models, which is spatially continuous and daily repeatable,
- retrieval of vegetation parameters over large areas, including spatial information on temporal dynamics
- validation/calibration of different sensors and observation geometries and
- datafusion in order to correct the image for bad pixels or clouds.

Possible disadvantages that strongly depend on the requested scale of the research objective are:

- a spatial and spectral information loss occurs due to the resampling and convolution process, which has to be performed,
- possible influence of a limited model performance (e.g. for modeled BRDF).

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